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(54) **SURFACE-GEOMETRY MEASUREMENT METHOD AND DEVICE USED THEREIN**

VERFAHREN ZUR MESSUNG EINER OBERFLÄCHENGEOMETRIE UND DARIN VERWENDETES VERFAHREN

PROCÉDÉ DE MESURE DE GÉOMÉTRIE DE SURFACE ET DISPOSITIF UTILISÉ POUR CELUI-CI

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Description

Technical Field

[0001] The present invention relates to a surface profile measurement method and a surface profile measurement device for measuring a surface profile of a three-dimensional object. For example, in particular, the present invention relates to a surface profile measurement method and a surface profile measurement device suitable for measuring an optical element, a reflective surface or a refractive surface of which consists of a curved surface, in a nondestructive manner and noncontact manner, highly accurately, and in a wide tilt angle dynamic range using light.

Background Art

[0002] As a technique for measuring a surface profile of a three-dimensional object in a nondestructive and noncontact manner and highly accurately using light, for example, as described in NPL 1 and United States Patent No. 5,398,113 specification (publication) (PTL 1), there has been a technique for combining a light source, which emits white light, and a dual beam interferometer and detecting, with a two-dimensional image sensor, an interference figure (an interferogram) obtained by causing reflected light from a micro region on a sample surface and reflected light from a standard plane incorporated in the dual beam interferometer to interfere with each other through an objective lens to thereby measure a height distribution of the sample surface. In this technique, in each of pixels of the two-dimensional image sensor, the reflected light from the sample surface made incident to an effective light sensing area of the pixel and the reflected light from the standard plane cause interference. At least during surface profile measurement of the sample, a surface orientation of the standard plane is fixed and used without being configured to be changed with respect to an incident optical axis of the reflected light. Information concerning a tilt angle distribution of the sample surface is not directly measured. JP-A-2006-242853 (PTL 2) discloses a technique including a mechanism for, instead of setting a standard plane having high surface accuracy as a standard plane, setting, in a dual beam interferometer used in monochromatic interferometry, a reference object having a surface profile substantially equal to a surface profile of a sample and adjusting a surface orientation of the standard plane.

[0003] On the other hand, as another conventional technique, for example, as described in pp. 306 to 307 of NPL 2, there is also a technique for measuring a tilt angle distribution on a sample surface using an autocollimator. In this technique, it is also possible to obtain a height distribution on the sample surface by integrating the tilt angle distribution.

[0004] The document US 2006/0221348 A1 discloses a surface profile measurement technique according to the preamble of claim 1. Further related methods and devices are disclosed in the documents JP H05 240628 A and JP 2002 202112 A.

Citation List

Patent Literature

[0005]

PTL 1: United State Patent No. 5,398,113
PTL 2: JP-A-2006-242853

Non Patent Literature

[0006]

NPL 1: "Advanced Metrology of Surface Texture by Scanning White Light Interferometry", Atsushi SATO, The journal of the Surface Finishing Society of Japan, Vo. 57. No. 8, pp. 554 to 558, issued in 2006

NPL 2: "A survey on surface metrology for flatness standard", Yohan KONDO, AIST bulletin of Metrology, Vol. 8, No. 3, pp. 299 to 310, issued in September 2011

Summary of Invention

Technical Problem

[0007] In the surface profile measurement technique of the white light interference system described in United State Patent No. 5,398,113 specification (publication) (PTL 1), wave fronts of the two reflected lights are parallel. That is, when an angle formed with respect to a surface orientation in a measured region corresponding to the pixel on the sample surface and an incident optical axis on the measured region and an angle formed by a surface orientation of the standard plane and an incident optical axis on the standard plane are the same, since an optical path difference between the two reflected lights is equal irrespective of a place in the pixel, a uniform interference effect is obtained. However, when the two wave fronts are not parallel and tilt at a certain angle each other, since the optical path difference changes between the two reflected lights according to a place in the pixel, the interference effect is not uniform. When a difference between optical path differences in the pixel is equal to or larger than an illumination wavelength, since the interference effect is cancelled by averaging, a surface profile cannot be measured. Further, to enable detection at a sufficient S/N without attenuating the interference effect, the difference between the optical path differences in the pixel needs to be kept within approximately a half of the illumination wavelength. In the technique, at least during surface profile measurement of the sample, the surface orientation of the standard plane is fixed and used without being configured to change with respect to the incident optical axis of the reflected light. Therefore, when the surface orientation in the measured region on the sample surface changes, a situation in which the interference effect is attenuated occurs in this way.

[0008] The width of each of the pixels is represented as d, a point image width of the objective lens is represented as d', the illumination wavelength is represented as λ, and a difference between the angle formed with respect to the surface orientation in the measured region corresponding to the pixel on the sample surface and the incident optical axis on the measured region and the angle formed by the surface orientation of the standard plane and the incident optical axis on the standard plane is represented as θ. The point image width d' indicates width from a foot on one side where the intensity of a point spread function of the objective lens is sufficiently small to a foot on the other side. In this case, d' is approximately 1.6 times as large as a Rayleigh limit often used in general as a resolution limit. If d is larger than d', when $d \cdot \tan 2\theta \geq \lambda/2$ Expression 1, attenuation of the interference effect occurs. If d is smaller than d', replacing d of Expression 1 with d', when $d' \cdot \tan 2\theta \geq \lambda/2$ Expression 2, attenuation of the interference effect occurs. In both the cases, to prevent the interference effect from being attenuated, the expression has to be $d' \cdot \tan 2\theta < \lambda/2$ Expression 3. When θ exceeds a range in which Expression 3 is satisfied, surface profile measurement is difficult. When visible light is used as the illumination light, the center wavelength of the visible light is approximately λ=600nm. In an objective lens having a large working distance suitable for the surface profile measurement, since a numerical aperture (NA) is as large as approximately NA=0.55, d' is equal to or larger than approximately 1.06 micrometers. At this point, when the inclination angle of the sample surface increases and $\theta \geq 7.9°$, Expression 3 is not satisfied. The surface profile measurement making use of the interference effect is difficult.

[0009] On the other hand, the technique disclosed in JP-A-2006-242853 (Patent Literature 2) includes a mechanism for adjusting the surface orientation of the standard plane. It is taken into account that the interference effect in a place with a large inclination angle on the sample surface is secured. However, the mechanism is used to optimize, on the entire sample surface, alignment between an optical axis in the dual beam interferometer and optical elements before height distribution measurement of the sample is started. The technique is based on the premise that the sample surface and the standard plane have substantially equal surface profile distributions. Therefore, a situation in which the surface geometries of the sample surface and the standard plane are locally different is not taken into account. The alignment is only performed for the entire sample surface. Therefore, in the technique, the height distribution itself of the sample surface cannot be directly obtained. Only a distribution of a deviation of the height of the sample surface with respect to a height distribution of the reference object surface set as the standard plane can be measured. A technique for measuring information concerning the tilt angle distribution of the sample surface is not included either. In this way, in the technique, a surface profile of a sample having any surface profile cannot be measured.

[0010] On the other hand, in the surface profile measurement technique for measuring a tilt angle distribution of a sample surface using the autocollimator described in pp. 306 to 307 of NPL 2, a measurement range of a high-precision autocollimator is approximately ± several ten seconds to ± several hundred seconds. A surface profile set as a measurement target is limited to a plane or a gentle curved surface. When the inclination angle of the sample surface increases, surface profile measurement is difficult.

[0011] The present invention has been devised in view of the above and it is an object of the present invention to provide a technique that can measure a surface profile of any test obj ect in a nondestructive manner and noncontact manner, highly accurately, and in a wide tilt angle dynamic range.

Solution to Problem

[0012] In order to attain the object, the present invention provides, in white light interference method using a dual beam interferometer, a technique for configuring a surface orientation of a standard plane to be changed with respect to an incident optical axis on the standard plane, acquiring, while relatively changing the surface orientation of the standard plane with respect to a local surface orientation in any position on a test surface, a plurality of interferograms generated by interference of reflected light from the test surface and reflected light from the standard plane, and calculating the local surface orientation on the test surface from the interferograms to thereby measure a surface profile of the test surface.

Advantageous Effect of Invention

[0013] In the present invention, it is possible to not only measure a surface profile of any test object in a nondestructive and noncontact manner using light but also measure the surface profile highly accurately and in a wide tilt angle dynamic range .

Brief Description of the Drawings

[0014]

[Fig. 1] Fig. 1 is a diagram showing the configuration of a surface profile measurement device according to a first embodiment of the present invention.
[Fig. 2(a)] Fig. 2(a) is a diagram showing an example of an interferogram according to the first embodiment of the present invention (in the case of a monochromatic light source).
[Fig. 2(b)] Fig. 2(b) is a diagram showing an example of an interferogram according to the first embodiment of the present invention (in the case of a broad spectral band light source) .
[Fig. 3] Fig. 3 is a diagram showing an operation flow of the surface profile measurement device according to the first embodiment of the present invention.
[Fig. 4] Fig. 4 is a diagram showing an effect at the time when a surface orientation of a standard plane is changed by the surface profile measurement device according to the first embodiment of the present invention.
[Fig. 5] Fig. 5 is a diagram showing the configuration of a surface profile measurement device according to a second embodiment of the present invention.

Description of Embodiments

[0015] Embodiments of the present invention are explained below with reference to the drawings.

<First Embodiment>

[0016] Fig. 1 is a diagram showing the configuration of a surface profile measurement device according to a first embodiment of the present invention. As a light source 1, a broad spectral band light source that generates light having a continuous wavelength such as a halogen lamp, a Xe lamp, or an LED is used. A light beam emitted from the light source 1 changes to a parallel beam 30 through an illumination optical system 2 including a lens or a reflection mirror for condensing and light beam parallelization and is made incident on a beam splitter 4 in a dual beam interferometer 3. The parallel beam 30 is divided into two light beams by the beam splitter 4. One divided light beam is reflected after being made incident on an illumination region 41 on the surface of a sample 40 through a sample-side objective lens 5, changes to a sample-side reflected light beam 31, and returns to the beam splitter 4 through the sample-side objective lens 5 again. The sample 40 is mounted on a sample moving stage 11 and is movable in orthogonal two axial directions (an X axis and a Y axis) and an optical axis direction (a Z axis) with respect to an optical axis of the sample-side objective lens 5. The X axis and the Y axis are used to move the position of the illumination region 41 on the sample 40. An X-coordinate value and a Y-coordinate value are controlled by an X-Y driving/control unit 12. The Z axis is driven by a piezo actuator 13 (not shown in the figure). A Z-coordinate value can be controlled by a Z-axis control unit 14 at resolution of approximately 1 nanometer. The other of the two light beams divided by the beam splitter 4 is made incident on a standard plane 7 through a reference-side objective lens 6 and thereafter changes to a reference-side reflected light beam 32 and returns to the beam splitter 4 through the reference-side objective lens 6 again. The sample-side objective lens 5 and the reference-side objective lens 6 are set such that distances from the beam splitter 4 are equal to each other. The standard plane 7 is set in a focusing position of the reference-side objective lens 6. An inclination angle of the standard plane 7 can be changed with respect to two axes orthogonal to an optical axis and corresponding to X and Y axes of the sample moving stage 11 by a two-axis inclining mechanism 15. In the following explanation, an inclination angle in a direction corresponding to the X axis is represented as θx and an inclination angle in a direction corresponding to the Y axis is represented as θy. θx and θy are respectively driven by piezo actuators 16 and 17 (not shown in the figure) . Angle control can be performed by an inclination-angle control unit 18 at resolution of approximately 5 micro-radians. The sample-side reflected light beam 31 and the reference-side reflected light beam 32 returning to the beam splitter 4 in this way are wave-optically combined to generate an interference light beam 33. After the interference light beam 33 is made incident on a focusing lens 8, a part of the interference light beam 33 passes through a field stop 9 set on a focusing surface of the focusing lens. The focusing lens 8 is adjusted to focus an image of the illumination region 41 on the focusing surface in a state in which the illumination region 41 is placed in a focusing position of the sample-side objective lens 5. The interference light beam 33 passed through the field stop 9 is lead to a photodetector 10. The light intensity of the interference light beam 33 is converted into an electric signal. The interference light beam 33 changes to an interference light intensity signal 34. The interference light intensity signal 34 is captured into the computer 21 through an A/D converter 20 and subjected to arithmetic processing. The computer 21 gives commands to the X-Y driving/control unit 12, the Z-axis control unit 14, and the inclination-angle control unit 18 and causes the units to change the X-coordinate value, the Y-coordinate value, the Z-coordinate value, and values of θx and θy.

[0017] In general, the dual beam interferometer represented by a Michelson interferometer artificially gives a change in a phase difference to between divided light beams and thereafter recombines the light beams, causes the light beams to interfere, and records a change in interference light intensity involved in the change in the phase difference. Numerical value data of the change in the interference light intensity involved in the change in the phase difference, a figure obtained by graphing the numerical value data, or an optical image obtained by spatially generating the change in the interference light intensity as a light amount distribution of light and shade is called interferogram (interference figure). The phase difference depends on an optical path difference between optical paths of tracing of the two light beams from the division to the recombination, that is, a difference between optical lengths and the wavelength of light in use. In the optical system in this embodiment, the optical path difference between the two light beams is a difference of an optical path of the beam splitter 4 → the sample-side objective lens 5 → the illumination region 41 on the sample 40 → the sample-side objective lens 5 → the beam splitter 4, and an optical length of an optical path of the beam splitter 4 → the reference-side objective lens 6 → the standard plane 7 → the reference-side objective lens 6 → the beam splitter 4. When the phase difference is represented as ϕ radians, the optical path difference between the two divided light beams is represented as ΔL micrometers, and a wavelength in use is represented as λ micrometers,

$$\phi = 2\pi\Delta L/\lambda \qquad \text{Expression 4}$$

is obtained. Therefore, the dual beam interferometer is often configured to place a reflection mirror in the optical path of one of the two light beams and translate the position of the reflection mirror to thereby change the optical length and record an interferogram. When a light source in use is a monochromatic light source that emits only light having a single wavelength, an equal interference light intensity change repeatedly occurs every time the optical path difference becomes twice as large as the wavelength of the light source. Therefore, an interferogram consisting of a single COS waveform shown in Fig. 2a is obtained. On the other hand, when a broad spectral band light source that generates light having a continuous wavelength is used, interference between two light beams is so-called white light interference. It is well known that, as shown in Fig. 2b, light intensity takes a maximum value in an optical path difference (a zero optical path difference) at which phase differences are substantially zero in common at wavelengths included in the light source and a vibration waveform is observed only around the optical path difference.

[0018] The operation of the computer 21 after the sample 40 is mounted on the sample moving stage 11 is explained using an operation flow in Fig. 3. Processing of the operation flow in Fig. 3 is incorporated in the computer 21 as an inclination-angle measuring function 50.

[0019] In this embodiment, as shown in Step 9 to Step 12, the computer 21 gives a command to the Z-axis control unit 14 and causes the Z-axis control unit 14 to move the Z-coordinate value from a predetermined initial position to an end position and captures the interference light intensity signal 34 to thereby record one interferogram. The initial position and the end position are determined to include the zero optical path difference. The shape of the interferogram obtained at this point is generally as shown in Fig. 2b. An amount serving as an interference contrast C is defined. When a light source inuse is amonochromatic light source, the interference contrast C is generally defined by the following expression. In the expression, the Z coordinate is changed to Z0, Z1, ..., and Zn at a fixed interval, interference light intensity in Zi is represented as Ji, max{Ji} represents a maximum value among J0, J1, ..., and Jn, and min{Ji} represents a minimum value.

$$C = [\max\{Ji\} - \min\{Ji\}] / [\max\{Ji\} + \min\{Ji\}] \qquad \text{Expression 5}$$

However, when a white light source is used, since the vibration waveform of the interference intensity is observed only around the zero optical path difference as shown in Fig. 2b and an envelope of vibration is attenuated as the optical path difference is further away from the zero optical path difference, the definition by the above expression is inappropriate. Therefore, in the present invention, the interference contrast C is defined by the following expression when a z coordinate of a zero optical path difference position is represented as Zc, the vibration waveform of the interference intensity is observed in a range of Za to Zb, and an average of the interference intensity {Ji} in a range of $a \leq i \leq b$ is represented as J0.

$$C=[\{\sum_{i=a}^{b}(Ji-J0)^2\}/(b-a+1)\}]^{(1/2)}/J0$$

Expression 6

[0020] Expression 6 is equal to a relative standard deviation of {Ji} in the range of a≤i≤b. The calculation of the interference contrast is performed in Step 13. In this embodiment, as shown in Step 5 to Step 15, the recording of one interferogram is performed every time the computer 21 gives a command to the inclination-angle control unit 18 and causes the inclination-angle control unit 18 to move θx and θy from predetermined initial positions to end positions by a predetermined pitch.

[0021] A result of an actually performed test using a dual beam interferometer same as the configuration in this embodiment is shown in Fig. 4. In the test, as the sample 40, a plane mirror 42, to an optical axis of which a predetermined inclination angle was given in advance, was placed, an inclination angle of the standard plane 7 was changed, and a relation between the inclination angle of the standard plane 7 obtained at that point and the interference contrast C was checked. As a result of the test, it was confirmed that the interference contrast C was maximized when the inclination angle of the plane mirror 42 placed as the sample and the inclination angle of the standard plane 7 were equal to each other. In this test, as differences from the configuration in this embodiment, the field stop 9 was detachably attachable, a CCD camera was able to be placed instead of the field stop 9, and an image formed when the interference light beam 33 was focused by the focusing lens 8 was able to be observed. As a result, it was found that, when the inclination angles of the plane mirror 42 and the standard plane 7 were different, interference fringes of light and shade appeared on an image acquired by the CCD camera, an interval of the interference fringes increased as the difference between the inclination angles decreased, and, when the inclination angles were equal and had no difference, the interference fringes were not observed. From the two test results, it is seen that, when the inclination angles of the plane mirror 42 and the standard plane 7 are equal, the optical path difference is equal in the entire region of the field stop 9 and the interference fringes of light and shade are not observed and, when the plane mirror 42 is moved in the optical axis direction, since all phases of light beams passing in the region uniformly change, the interference contrast C is maximized. In general, a surface profile of the sample 40 needs to be considered a non-plane. However, the surface profile in the illumination region 41 in a microscopic sense can be approximately regarded as being sufficiently a plane under an optical microscope. Therefore, from the test results, it is seen that an inclination angle of a local micro plane in the illumination region 41 on the sample 40 can be measured by detecting an inclination angle of the standard plane 7 at the time when the interference contrast C is maximized. Even when the inclination angle of the plane mirror 42 increases, by also increasing the inclination angle of the standard plane 7 according to the increase in the inclination angle, the phases of the light beams passing in the region can be uniformly aligned and the interference contrast can be secured.

[0022] Referring back to the operation flow in Fig. 3, in this embodiment, in Step 16, a set of (θx, θy) for maximizing the interference contrast C is detected. In order to obtain a set of (θx, θy) serving as a solution at high accuracy, in Step 14 and Step 15, it is necessary to set the pitch in moving θx and θy sufficiently fine. However, as shown in Fig. 4, the interference contrast C shows only an extremely gentle change with respect to a change in θx and θy near a maximum point of the interference contrast C. When a measurement result of the interference contrast C wavers because of superimposition of noise, a large error is caused. Therefore, in the present invention, in Step 16, a predetermined fitting function F(θx, θy) is fit to numerical values of a plurality of interference contrasts C obtained in Step 5 to Step 15 by a method of least squares using a value of (θx, θy) corresponding to a vertex position as an unknown number. A set of (θx, θy) obtained as a most matching result is adopted as a solution. The set of (θx, θy) obtained at this point is measurement values of inclination angles in two axial directions of X-Y on the local micro plane in the illumination region 41 on the sample 40 mounted on the sample moving stage 11. In order to obtain inclination angles for all surfaces on the sample 40, as shown in Step 1 to Step 18, the sample moving stage 11 is moved in the X-Y directions and the processing shown in Step 5 to Step 16 is repeated. In this way, in this embodiment, a tilt angle distribution (θx, θy) can be measured on the all the surfaces on the sample 40.

[0023] The inclination angles (θx, θy) in the two axial directions of X-Y on the local micro plane in the illumination region 41 on the sample 40 mounted on the sample moving stage 11 are differential values of a sample surface Z=F(X, Y) in the local plane position. That is,

$$\theta x=\partial F(X, Y)/\partial X, \quad \theta y=\partial F(X, Y)/\partial Y \qquad \text{Expression 7}$$

Therefore, by integrating (θx, θy) on a two-dimensional plane of X-Y by giving an appropriate initial value, conversely, it is possible to reconstruct a distribution of Z=F(X, Y). In this embodiment, the computer 21 also includes an inclination angle/height converting function 51 for converting an inclination angle into Z height according to this integration conversion. It is possible to calculate a height distribution Z=F (X, Y) from the distribution of the inclination angles (θx, θy) measured as explained above.

[0024] In this way, in this embodiment, a height distribution and a tilt angle distribution can be measured as a surface profile of any test object in a nondestructive manner and noncontact manner, highly accurately, and in a wide tilt angle dynamic range using light.

<Second Embodiment>

[0025] A second embodiment of the present invention is explained with reference to Fig. 5, which is a configuration diagram in the second embodiment.

[0026] In this embodiment, a mechanism for measuring the height Z of the local micro plane in the illumination region 41 on the sample 40 is added to the first embodiment to make it possible to evaluate an up-down fluctuation characteristic of a sample moving stage. As explained above, in the first embodiment, it is possible to calculate the height distribution Z=F(X, Y) by directly measuring the distribution of the inclination angles (θx, θy). However, in addition to this, this embodiment has a function of directly measuring the height distribution Z=F (X, Y) using a dual beam interferometer. An optically directly measured height distribution is represented as Z1=F1 (X, Y) and a height distribution calculated by integrating a tilt angle distribution is represented as Z2=F2 (X, Y) to distinguish the height distributions. In Z1, not only height information of the sample 40 but also undesired up-down height fluctuation of the stage surface in driving the sample moving stage 11 to move the measurement position is included as an error. On the other hand, when the stage surface moves up and down according to the driving, if fluctuation in an angle direction is sufficiently small, since inclination angle measurement is hardly affected by the fluctuation, Z2 does not involve an error. Therefore, it is possible to evaluate a height fluctuation characteristic of the sample moving stage 11 by calculating a difference of Z1-Z2. Therefore, in this embodiment, in the computer 21, a height measuring function 52 and a height-difference detecting function 53 are provided in addition to the inclination-angle measuring function 50 and the inclination angle/height converting function 51. The other components are the same as the components in the first embodiment.

[0027] In this embodiment configured as explained above, besides the effects obtained in the first embodiment, it is possible to evaluate the up-down fluctuation characteristic of the sample moving stage.

Reference Signs List

[0028]

1	Light source
2	Illumination optical system
3	Dual beam interferometer
4	Beam splitter
5	Sample-side objective lens
6	Reference-side objective lens
7	Standard plane
8	Focusing lens
9	Field stop
10	Photodetector
11	Sample moving stage
12	X-Y driving/control unit
13, 16, 17	Piezo actuators
14	Z-axis control unit
15	Two-axis inclining mechanism
18	Inclination-angle control unit
20	A/D converter
21	Computer
30	Parallel beam
31	Sample-side reflected light beam
32	Reference-side reflected light beam
33	Interference light beam
34	Interference light intensity signal

35	Interferogram
40	Sample
41	Illumination region
50	Inclination-angle measuring function
51	Inclination angle/height converting function
52	Height measuring function
53	Height-difference detecting function

Claims

1. A surface profile measurement method including the steps of dividing an illumination light beam emitted from a light source (1) continuously or discretely having a predetermined wavelength bandwidth into two light beams and making the light beams incident on a test surface and a standard plane (7), and causing a reflected light beam (31) from the test surface and a reflected light beam (32) from the standard plane (7) to interfere in an interferometer (3) to measure a surface profile of the test surface, **characterized by** further including the steps of:

- changing a surface orientation in the illumination light beam incident position on the standard plane (7)
- measuring a local surface orientation of the test surface in each of a plurality of positions on the test surface, and
- obtaining, from surface orientation data measured in two or more positions on the test surface, surface height calculation values of the test surface in the positions according to integration processing.

2. The surface profile measurement method according to claim 1 , wherein the surface orientation in the illumination light beam incident position on the standard plane (7) is changed by using a plane mirror as the standard plane (7), inclining or rotating the surface orientation of the standard plane (7) in two axial directions orthogonal to each other and both orthogonal to an optical axis.

3. The surface profile measurement method according to claim 1 , wherein the surface orientation in the illumination light beam incident position on the standard plane (7) is changed by using, as the standard plane, a curved surface mirror, a local surface orientation of a reflective surface of which continuously or discretely changes in two axial directions orthogonal to each other and both orthogonal to an optical axis, and translating the entire standard plane (7) in the two axial directions orthogonal to the optical axis.

4. The surface profile measurement method according to any one of claims 1 to 3 , wherein the surface profile measurement method includes the steps of measuring a local surface orientation of the test surface by changing the surface orientation of the standard plane (7) relative to a local surface orientation in any position on the test surface and calculating a surface orientation of the standard plane (7) at a time when the local surface orientation on the test surface and a surface orientation in the illumination light beam incident position on the standard plane (7) are equal.

5. The surface profile measurement method according to claim 4 , wherein:
the surface profile measurement method includes the steps of determining that, when an interference contrast is maximized in an interferogram obtained by interference of a reflected light beam from the test surface and a reflected light beam from the standard plane (7), the local surface orientation on the test surface and the surface orientation of the standard plane (7) are equal, and preferably:
the surface profile measurement method further includes the steps of calculating a relative standard deviation from interference intensity data configuring the interferogram and using the relative standard deviation as the interference contrast.

6. The surface profile measurement method according to claim 5 , wherein the surface profile measurement method further includes the steps of calculating a surface orientation of the standard plane (7) at the time when the interference contrast is maximized, matching a predetermined interference contrast distribution function with a plurality of interference contrast values, which are measured by roughly discretely changing the surface orientation, using a surface orientation corresponding to the maximum value of the interference contrast as an unknown number, and calculating the surface orientation as a surface orientation at a time when the interference contrast distribution function most matches the interference contrast value.

7. The surface profile measurement method according to any one of claims 1 to 6, further including measuring both of a local surface orientation and height of the test surface using an interferogram (35) obtained in any position on the test surface.

8. The surface profile measurement method according to claim 7, wherein:
the surface profile measurement method includes the steps of irradiating , as the illumination light beam, illumination light continuously or discretely having a predetermined wavelength bandwidth on the test surface and the standard plane (7), or:
using, as the illumination light beam, a light source continuously or discretely having a predetermined wavelength bandwidth for measuring the height for measuring the local surface orientation, and simultaneously or sequentially irradiating illumination lights from the light sources (1) on the test surface and the standard plane (7).

9. The surface profile measurement method according to any one of the preceding claims, wherein the surface profile measurement method includes using a sample moving stage (11) for moving a position of a sample (40) having the test surface in order to change a measurement position on the test surface, the method further including a function of obtaining, from surface orientation data measured in two or more positions on the test surface, surface height calculation values in the positions according to integration processing, and a function of comparing surface heights measured in the positions and the surface height calculation values.

10. The surface profile measurement method according to claim 9, wherein the surface profile measurement method further includes the steps of obtaining, on the basis of a result obtained by comparing the surface heights measured in the positions and the surface height calculation values, a height fluctuation distribution of the entire sample involved in movement of the sample moving stage (11).

11. A surface profile measurement device comprising:

a light source (1) continuously or discretely having a predetermined wavelength bandwidth;
an interferometer (3) including a beam splitter (4), a standard plane (7), a first objective lens (5), a second objective lens (6), and a sample moving stage (11), the interferometer (3) being configured to divide, with the beam splitter (4), an illumination light beam into a measurement light beam and a reference light beam, reciprocatingly propagate the measurement light beam between the beam splitter (4) and a test surface through the first objective lens (5), and reciprocatingly propagate the reference light beam between the beam splitter (4) and the standard plane (7) through the second objective lens (6) manufactured to have a characteristic which is the same as a characteristic of the first objective lens (5), the sample moving stage (11) being capable of mounting the sample (40) including the test surface and moving a measurement position and changing a relative distance in a direction along an optical axis of the measurement light beam between the sample (40) and the first objective lens (5), after giving a change to an optical path difference represented by a relative difference between an optical length for reciprocatingly propagating the measurement light beam between the beam splitter (4) and the test surface and an optical length for reciprocatingly propagating the reference light beam between the beam splitter (4) and the standard plane (7), the interferometer (3) recombining the measurement light beam and the reference light beam after the reciprocating propagation and causing the light beams to interfere;
a control unit (12, 14, 21) configured to control the sample moving stage (11) and the interferometer (3);
a photodetector (10) configured to convert an intensity of interference light obtained by the interferometer (3) into an electric signal; and
a data processing unit (21) configured to process an output signal of the photodetector (10),
the surface profile measurement device being configured to control the sample stage (11) and the interferometer (3) in a plurality of sampling positions on the test surface and to subject an output signal output from the photodetector (10) to calculation processing in the data processing unit (21) to thereby measure a surface profile of the test surface, wherein
the standard plane (7) of the interferometer is a plane mirror, a surface orientation of the standard plane (7) is capable of inclining or rotating in two axial directions orthogonal to each other or both orthogonal to an optical axis,

characterized in that the control unit (21) is configured to change, for each of said plurality of sampling positions, the surface orientation of the standard plane (7) in the two axial directions and change a position of the sample moving stage (11) in a direction along an optical axis of the measurement light beam to thereby change the optical path difference, the photodetector (10) is configured to convert an intensity change of the interference light involved in a change in the surface orientation and the optical path difference into an electric signal, the data processing unit (21) is configured to subject a change in the electric signal to calculation processing to detect local surface orientations of the test surface in each of the sampling positions on the test surface, wherein the surface profile measurement device further includes a function of obtaining, from surface orientation data measured in two or more positions on the test surface, surface height calculation values of the test surface in the positions according to integration processing.

12. The surface profile measurement device according to claim 11 , wherein, in the detection of the local surface orientation, the surface profile measurement device is configured to change the surface orientation of the standard plane (7) to a plurality of orientations stepwise in the two axial directions, match a predetermined interference contrast distribution function with an interference contrast of the interference light observed when the optical path difference is scanned in a predetermined range using, as an unknown number, a surface orientation corresponding to a maximum value of the interference contrast, and to calculate the surface orientation as a surface orientation at a time when the interference contrast distribution function most matches the interference contrast value.

13. The surface profile measurement device according to any one of claims 11 to 12, wherein the surface profile measurement device is configured to measure both of a local surface orientation and height of the test surface using an interferogram (35) obtained in any position on the test surface (7).

Patentansprüche

1. Oberflächenprofil-Messverfahren mit den Schritten des Aufteilens eines kontinuierlich oder diskret von einer Lichtquelle (1) emittierten Beleuchtungslichtstrahls mit einer vorbestimmten Wellenlängenbandbreite in zwei Lichtstrahlen, des Auftreffenlassens der Lichtstrahlen auf eine Testfläche und eine Normalebene (7) und des Bewirkens, dass ein reflektierter Lichtstrahl (31) von der Testfläche und ein reflektierter Lichtstrahl (32) von der Normalebene (7) in einem Interferometer (3) interferieren, um ein Oberflächenprofil der Testoberfläche zu messen,
dadurch gekennzeichnet, dass es ferner die folgenden Schritte umfasst:

- Ändern einer Oberflächenorientierung der Position auf der Normalebene (7) in welcher der Beleuchtungslichtstrahl auftrifft;
- Messen einer lokalen Oberflächenorientierung der Testoberfläche in jeder einer Vielzahl von Positionen auf der Testoberfläche; und
- Ermitteln von Oberflächenhöhenberechnungswerten der Testoberfläche gemäß einer Integrationsverarbeitung aus Oberflächenorientierungsdaten, die an zwei oder mehr Positionen auf der Testoberfläche gemessen werden, in den Positionen.

2. Oberflächenprofil-Messverfahren nach Anspruch 1,
dadurch gekennzeichnet, dass die Oberflächenorientierung in der Position auf der Normalebene (7), in welcher der Beleuchtungslichtstrahl auftrifft, durch Verwendung eines flachen Spiegels als Normalebene (7) geändert wird, wobei die Oberflächenorientierung der Normalebene (7) in zwei zueinander orthogonalen Achsenrichtungen, die beide orthogonal zu einer optischen Achse verlaufen, geneigt oder gedreht wird.

3. Oberflächenprofil-Messverfahren nach Anspruch 1,
wobei die Oberflächenorientierung in der Position auf der Normalebene (7), in welcher der Beleuchtungslichtstrahl auftrifft, geändert wird, indem als Normalebene ein Spiegel mit gekrümmter Oberfläche verwendet wird, dessen lokale Oberflächenorientierung seiner reflektierenden Oberfläche sich kontinuierlich oder diskret in zwei Achsenrichtungen verändert, die orthogonal zueinander und beide orthogonal zu einer optischen Achse verlaufen, und die gesamte Normalebene (7) in den zwei Achsenrichtungen orthogonal zur optischen Achse verschoben wird.

4. Oberflächenprofil-Messverfahren nach einem der Ansprüche 1 bis 3,
wobei das Oberflächenprofil-Messverfahren die Schritte des Messens einer lokalen Oberflächenorientierung der Testoberfläche durch Ändern der Oberflächenorientierung der Normalebene (7) relativ zu einer lokalen Oberflächenorientierung in jeder Position auf der Testoberfläche und des Berechnens einer Oberflächenorientierung der Normalebene (7) in einem Zeitpunkt, in dem die lokale Oberflächenorientierung auf der Testoberfläche und eine Oberflächenorientierung in der Position auf der Normalebene (7), in welcher der Beleuchtungslichtstrahl auftrifft, gleich sind, umfasst.

5. Oberflächenprofil-Messverfahren nach Anspruch 4,
wobei
das Oberflächenprofil-Messverfahren die Schritte des Bestimmens, dass, wenn ein Interferenzkontrast in einem

durch Interferenz eines von der Testoberfläche reflektierten Lichtstrahls und eines von der Normalebene (7) reflektierten Lichtstrahls erhaltenen Interferogramm maximiert wird, die lokale Oberflächenorientierung auf der Testfläche und der Oberflächenorientierung der Normalebene (7) gleich sind, umfasst und vorzugsweise:
das Oberflächenprofil-Messverfahren ferner die Schritte des Berechnens einer relativen Standardabweichung von Interferenzintensitätsdaten, die das Interferogramm bilden, und des Verwendens der relativen Standardabweichung als Interferenzkontrast umfasst.

6. Oberflächenprofil-Messverfahren nach Anspruch 5,
wobei das Oberflächenprofil-Messverfahren ferner die Schritte des Berechnens einer Oberflächenorientierung der Normalebene (7) in dem Zeitpunkt, in dem der Interferenzkontrast maximiert ist, mit einer vorbestimmten Interferenzkontrastverteilungsfunktion mit einer Vielzahl von Interferenzkontrastwerten, die gemessen werden, indem die Oberflächenorientierung grob schrittweise geändert wird, umfasst, wobei eine Oberflächenorientierung verwendet wird, die dem Maximalwert des Interferenzkontrastes als eine unbekannte Zahl entspricht, und die Oberflächenorientierung als eine Oberflächenorientierung in einem Zeitpunkt berechnet wird, in dem die Interferenzkontrastverteilungsfunktion am besten mit dem Interferenzkontrastwert übereinstimmt.

7. Oberflächenprofil-Messverfahren nach einem der Ansprüche 1 bis 6,
ferner umfassend das Messen sowohl einer lokalen Oberflächenorientierung als auch der Höhe der Testoberfläche unter Verwendung eines Interferogramms (35), das in irgendeiner Position auf der Testoberfläche ermittelt wird.

8. Oberflächenprofil-Messverfahren nach Anspruch 7,
wobei das Oberflächenprofilmessverfahren die Schritte des kontinuierlichen oder diskreten Bestrahlens der Testoberfläche und der Normalebene (7) mit Beleuchtungslicht als Beleuchtungslichtstrahl mit einer vorbestimmten Wellenlängenbandbreite, oder
des Verwendens einer Beleuchtungsquelle als kontinuierlicher oder diskreter Beleuchtungslichtstrahl, die eine vorbestimmte Wellenlängenbandbreite aufweist, umfasst, um die Höhe zum Messen der lokalen Oberflächenorientierung zu messen, und
gleichzeitiges oder sequentielles Bestrahlen der Testoberfläche und der Normalebene (7) mit Beleuchtungslicht aus den Lichtquellen (1).

9. Oberflächenprofil-Messverfahren nach einem der vorhergehenden Ansprüche,
wobei das Oberflächenprofil-Messverfahren das Verwenden eines Probenbewegungstisches (11) zum Bewegen einer Position einer Probe (40) mit der Testoberfläche umfasst, um eine Messposition auf der Testoberfläche zu ändern, wobei das Verfahren ferner eine Funktion des Ermittelns von Oberflächenrichtungsdaten, die in zwei oder mehr Positionen auf der Testoberfläche gemessen werden, Oberflächenhöhenberechnungswerten an den Positionen gemäß der Integrationsverarbeitung und eine Funktion des Vergleichens von Oberflächenhöhen, die in den Positionen gemessen wurden, mit den Oberflächenhöhenberechnungswerten umfasst.

10. Oberflächenprofil-Messverfahren nach Anspruch 9, wobei das Oberflächenprofil-Messverfahren ferner die Schritte des Ermittelns einer Höhenschwankungsverteilung der gesamten Probe auf der Basis eines Ergebnisses umfasst, welches durch Vergleichen der an den Positionen gemessenen Oberflächenhöhen und der Oberflächenhöhenberechnungswerte erhalten wird, und die mit der Bewegung der Probenbewegungsstufe (11) einher geht.

11. Oberflächenprofil-Messvorrichtung, umfassend:

eine kontinuierliche oder diskrete Lichtquelle (1), die eine vorbestimmte Wellenlängenbandbreite aufweist;
ein Interferometer (3) mit einem Strahlteiler (4), einer Normalebene (7), einer ersten Objektivlinse (5), einer zweiten Objektivlinse (6) und einem Probenbewegungstisch (11), wobei das Interferometer (3) dazu ausgelegt ist, mit dem Strahlteiler (4) einen Beleuchtungslichtstrahl in einen Messlichtstrahl und einen Referenzlichtstrahl aufzuteilen, den Messlichtstrahl zwischen dem Strahlteiler (4) und einer Testoberfläche durch die erste Objektivlinse (5) hin und her zu reflektieren und den Referenzlichtstrahl zwischen dem Strahlteiler (4) und der Normalebene (7) durch die zweite Objektivlinse (6) hin und her zu reflektieren, die so hergestellt ist, dass sie eine Charakteristik aufweist, die der Charakteristik der ersten Objektivlinse (5) entspricht, wobei die Probe (40) einschließlich der Testoberfläche auf dem
Probenbewegungstisch (11) montiert werden kann und in eine Messposition bewegen kann und ein relativer Abstand zwischen der Probe (40) und der erste Objektivlinse (5) in einer Richtung entlang einer optischen Achse des Messlichtstrahls verändert werden kann, nachdem eine optischen Wegdifferenz geändert wurde, die dargestellt wird durch eine relative Differenz zwischen einem optischen Weg des Hin - und Herlaufens des

Messlichtstrahls zwischen dem Strahlteiler (4) und der Testoberfläche und eine optischen Weg des Hin - und Herlaufens des Referenzlichtstrahls zwischen dem Strahlteiler (4) und der Normalebene (7),
wobei das Interferometer (3) den Messlichtstrahl und den Referenzlichtstrahl nach der Hin - und Herreflexion zusammenführt und bewirkt, dass die Lichtstrahlen interferieren;
eine Steuereinheit (12, 14, 21), die dazu ausgelegt ist, den Probenbewegungstisch (11) und das Interferometer (3) zu steuern;
einen Photodetektor (10), der dazu ausgelegt ist, eine Intensität von Interferenzlicht, das von dem Interferometer (3) gewonnen wird, in ein elektrisches Signal umzuwandeln; und
eine Datenverarbeitungseinheit (21), die dazu ausgelegt ist, ein Ausgangssignal des Photodetektors (10) zu verarbeiten,
wobei die Oberflächenprofil-Messvorrichtung dazu ausgelegt ist, den Probentisch (11) und das Interferometer (3) in eine Mehrzahl von Abtastpositionen auf der Testoberfläche zu bewegen und ein Ausgangssignal des Photodetektors (10) einer Berechnungsverarbeitung Datenverarbeitungseinheit (21) zu unterziehen, um dadurch ein Oberflächenprofil der Testoberfläche zu messen, wobei:

die Normalebene (7) des Interferometers ein flacher Spiegel ist,
wobei eine Oberflächenorientierung der Normalebene (7) in zwei zueinander orthogonalen oder beide orthogonal zu einer optischen Achse verlaufenden optischen Achsen geneigt oder geschwenkt werden kann,
dadurch gekennzeichnet, dass die Steuereinheit (21) dazu ausgelegt ist, für jede der Vielzahl von Abtastpositionen die Oberflächenorientierung der Normalebene (7) in den zwei Achsenrichtungen zu ändern und eine Position des Probenbewegungstischs (11) in einer Richtung einer optischen Achse des Messlichtstrahls zu ändern, um dadurch die optische Wegdifferenz zu ändern, wobei der Photodetektor (10) dazu ausgelegt ist, eine Intensitätsänderung des Interferenzlichts, die mit einer Änderung der Oberflächenorientierung und der optischen Wegdifferenz einher geht, in ein elektrisches Signal umzuwandeln, die Datenverarbeitungseinheit (21) dazu ausgelegt ist, eine Änderung des elektrischen Signals einer Berechnungsverarbeitung zu unterwerfen, um lokale Oberflächenorientierungen der Testoberfläche in jeder der Probenposition auf der Testoberfläche zu detektieren,
wobei die Oberflächenprofil-Messvorrichtung ferner eine Funktion des Ermittelns von Oberflächenhöhenberechnungswerten der Testoberfläche an den Positionen gemäß der Integrationsverarbeitung aus Oberflächenmessungsdaten, die an zwei oder mehr Positionen auf der Testoberfläche gemessen werden, umfasst.

12. Oberflächenprofil-Messvorrichtung nach Anspruch 11,
dadurch gekennzeichnet, dass die Oberflächenprofil-Messvorrichtung (10) zur Detektion der lokalen Oberflächenorientierung dazu ausgelegt ist, die Oberflächenorientierung der Normalebene (7) schrittweise in mehrere Orientierungen den beiden Achsenrichtungen zu ändern, eine vorbestimmte Interferenzkontrastverteilungsfunktion mit einem Interferenzkontrast des Interferenzlichts in Übereinstimmung zu bringen, der beobachtet wird, wenn die optische Wegdifferenz in einem vorbestimmten Bereich unter Verwendung einer Oberflächenorientierung, die einem maximalen Wert des Interferenzkontrastes als eine unbekannte Größe entspricht, abgetastet wird und die Oberflächenorientierung als eine Oberflächenorientierung in einem Zeitpunkt zu berechnen, in dem die Interferenzkontrastverteilungsfunktion am besten zu dem Interferenzkontrastwert passt.

13. Oberflächenprofilmessvorrichtung nach einem der Ansprüche 11 bis 12, wobei die Oberflächenprofilmessvorrichtung dazu ausgelegt ist, sowohl eine lokale Oberflächenorientierung als auch eine Höhe der Testoberfläche unter Verwendung eines Interferogramms (35) zu messen, das in irgendeiner Position an der Testoberfläche (7) gewonnen wird.

Revendications

1. Procédé de mesure de profil de surface incluant les étapes de division d'un faisceau de lumière d'éclairage émis depuis une source (1) de lumière de manière continue ou discrète ayant une largeur de bande de longueur d'onde prédéterminée en deux faisceaux de lumière, le fait de rendre les faisceaux de lumière incidents sur une surface de test et un plan standard (7), et le fait de faire en sorte qu'un faisceau de lumière réfléchi (31) depuis la surface de test et qu'un faisceau de lumière réfléchi (32) depuis le plan standard (7) interfèrent dans un interféromètre (3) pour mesurer un profil de surface de la surface de test, **caractérisé en ce qu'**incluant en outre les étapes de :

- changement d'une orientation de surface dans la position incidente de faisceau de lumière d'éclairage sur le plan standard (7),
- mesure d'une orientation de surface locale de la surface de test dans chacune d'une pluralité de positions sur la surface de test, et
- obtention, à partir de données d'orientation de surface mesurées dans deux positions ou plus sur la surface de test, de valeurs de calcul de hauteur de surface de la surface de test dans les positions conformément à un traitement d'intégration.

2. Procédé de mesure de profil de surface selon la revendication 1, dans lequel l'orientation de surface dans la position incidente de faisceau de lumière d'éclairage sur le plan standard (7) est changée en utilisant un miroir plan comme le plan standard (7), en inclinant ou en faisant tourner l'orientation de surface du plan standard (7) dans deux directions axiales orthogonales l'une par rapport à l'autre et toutes les deux orthogonales par rapport à un axe optique.

3. Procédé de mesure de profil de surface selon la revendication 1, dans lequel l'orientation de surface dans la position incidente de faisceau de lumière d'éclairage sur le plan standard (7) est changée en utilisant, comme le plan standard, un miroir à surface incurvée, dont une orientation de surface locale d'une surface réfléchissante change de manière continue ou discrète dans deux directions axiales orthogonales l'une par rapport à l'autre et toutes les deux orthogonales par rapport à un axe optique, et par une translation de la totalité du plan standard (7) dans les deux directions axiales orthogonales par rapport à l'axe optique.

4. Procédé de mesure de profil de surface selon l'une quelconque des revendications 1 à 3, dans lequel le procédé de mesure de profil de surface inclut les étapes de mesure d'une orientation de surface locale de la surface de test en changeant l'orientation de surface du plan standard (7) par rapport à une orientation de surface locale en une position quelconque sur la surface de test et de calcul d'une orientation de surface du plan standard (7) à un moment où l'orientation de surface locale sur la surface de test et une orientation de surface dans la position incidente de faisceau de lumière d'éclairage sur le plan standard (7) sont égales.

5. Procédé de mesure de profil de surface selon la revendication 4, dans lequel :
le procédé de mesure de profil de surface inclut les étapes de détermination que, lorsqu'un contraste d'interférence est maximisé dans un interférogramme obtenu par une interférence d'un faisceau de lumière réfléchie depuis la surface de test et d'un faisceau de lumière réfléchie depuis le plan standard (7), l'orientation de surface locale sur la surface de test et l'orientation de surface du plan standard (7) sont égales et, préférablement :
le procédé de mesure de profil de surface inclut en outre les étapes de calcul d'un écart type relatif à partir de données d'intensité d'interférence configurant l'interférogramme et d'utilisation de l'écart type relatif comme le contraste d'interférence.

6. Procédé de mesure de profil de surface selon la revendication 5, dans lequel le procédé de mesure de profil de surface inclut les étapes de calcul d'une orientation de surface du plan standard (7) au moment où le contraste d'interférence est maximisé, de mise en correspondance d'une fonction prédéterminée de distribution de contraste d'interférence avec une pluralité de valeurs de contraste d'interférence, qui sont mesurées en changeant grossièrement discrètement l'orientation de surface, d'utilisation d'une orientation de surface correspondant à la valeur maximum du contraste d'interférence comme un nombre inconnu, et de calcul de l'orientation de surface comme une orientation de surface à un moment où la fonction de distribution de contraste d'interférence correspond le plus à la valeur de contraste d'interférence.

7. Procédé de mesure de profil de surface selon l'une quelconque des revendications 1 à 6, incluant en outre la mesure à la fois d'une orientation de surface locale et d'une hauteur de la surface de test en utilisant un interférogramme (35) obtenu en une position quelconque sur la surface de test.

8. Procédé de mesure de profil de surface selon la revendication 7, dans lequel :

le procédé de mesure de profil de surface inclut les étapes de projection, comme le faisceau de lumière d'éclairage, d'une lumière d'éclairage ayant de manière continue ou discrète une largeur de bande de longueur d'onde prédéterminée sur la surface de test et le plan standard (7), ou :
d'utilisation, comme le faisceau de lumière d'éclairage, d'une source de lumière ayant de manière continue ou discrète une largeur de bande de longueur d'onde prédéterminée pour mesurer la hauteur pour mesurer l'orientation de surface locale, et simultanément ou séquentiellement de projection de lumières d'éclairage depuis les sources (1) de lumière sur la surface de test et le plan standard (7).

9. Procédé de mesure de profil de surface selon l'une quelconque des revendications précédentes, dans lequel le procédé de mesure de profil de surface inclut l'utilisation d'une platine mobile (11) pour échantillon pour déplacer une position d'un échantillon (40) ayant la surface de test afin de changer une position de mesure sur la surface de test, le procédé incluant en outre une fonction d'obtention, à partir de données d'orientation de surface mesurées dans deux positions ou plus sur la surface de test, de valeurs de calcul de hauteur de surface dans les positions conformément à un traitement d'intégration, et une fonction de comparaison de hauteurs de surface mesurées dans les positions et des valeurs de calcul de hauteur de surface.

10. Procédé de mesure de profil de surface selon la revendication 9, dans lequel le procédé de mesure de profil de surface inclut en outre les étapes d'obtention, sur la base d'un résultat obtenu en comparant les hauteurs de surface mesurées dans les positions et les valeurs de calcul de hauteur de surface, d'une distribution de fluctuation de hauteur de la totalité de l'échantillon impliqué dans un mouvement de la platine mobile (11) pour échantillon.

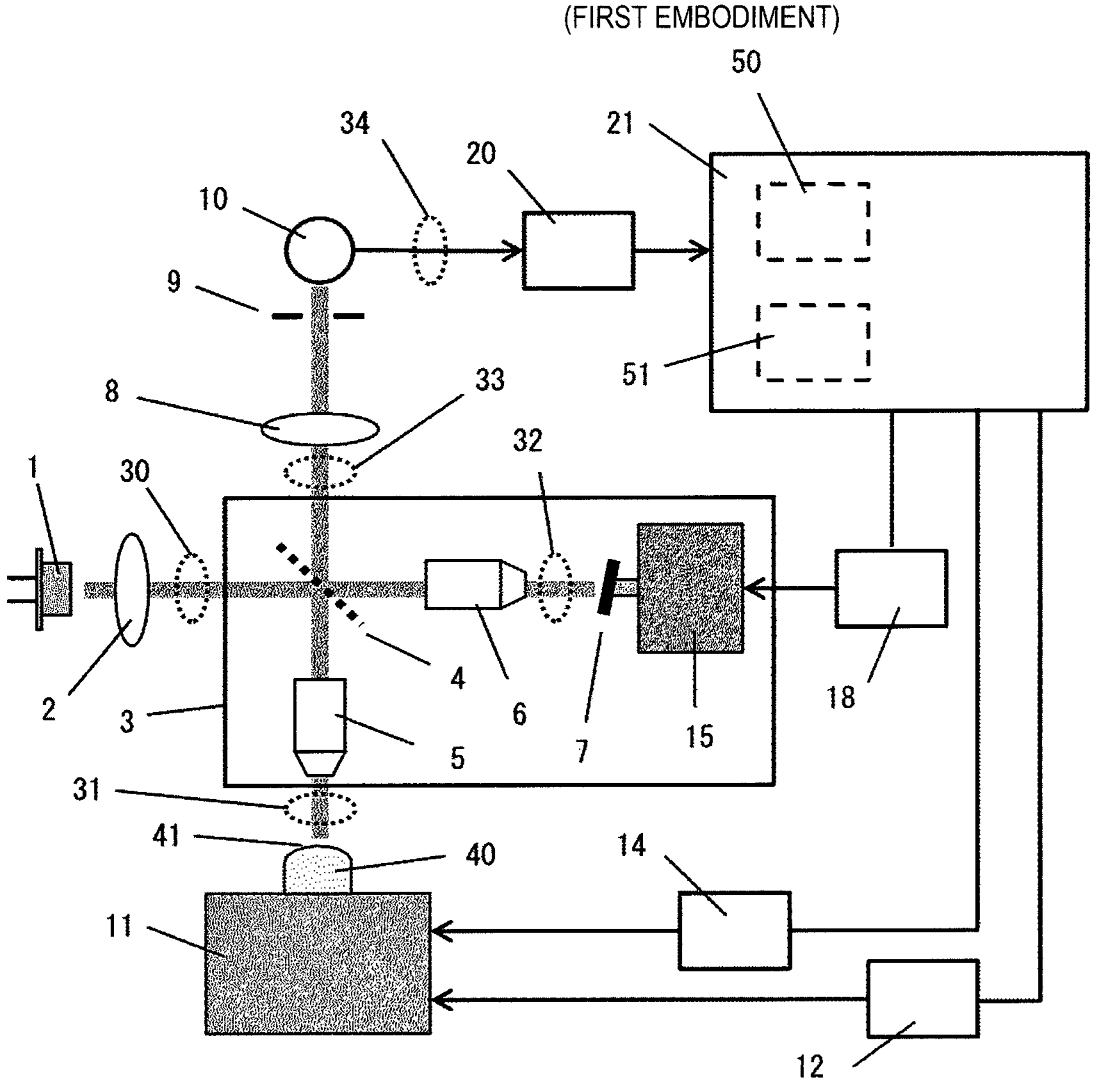
11. Dispositif de mesure de profil de surface comprenant :

une source (1) de lumière ayant de manière continue ou discrète une largeur de bande de longueur d'onde prédéterminée ;
un interféromètre (3) incluant un diviseur (4) de faisceau, un plan standard (7), un premier objectif (5), un deuxième objectif (6), et une platine mobile (11) pour échantillon, l'interféromètre (3) étant configuré pour diviser, avec le diviseur (4) de faisceau, un faisceau de lumière d'éclairage en un faisceau de lumière de mesure et un faisceau de lumière de référence, propager de manière alternée le faisceau de lumière de mesure entre le diviseur (4) de faisceau et une surface de test à travers le premier objectif (5), et propager de manière alternée le faisceau de lumière de référence entre le diviseur (4) de faisceau et le plan standard (7) à travers le deuxième objectif (6) fabriqué pour avoir une caractéristique qui est la même qu'une caractéristique du premier objectif (5), la platine mobile (11) pour échantillon étant apte à monter l'échantillon (40) incluant la surface de test et à déplacer une position de mesure et à changer une distance relative dans une direction le long d'un axe optique du faisceau de lumière de mesure entre l'échantillon (40) et le premier objectif (5), après avoir donné un changement à une différence de chemin optique représentée par une différence relative entre une longueur optique pour propager de manière alternée le faisceau de lumière de mesure entre le diviseur (4) de faisceau et la surface de test et une longueur optique pour propager de manière alternée le faisceau de lumière de référence entre le diviseur (4) de faisceau et le plan standard (7), l'interféromètre (3) recombinant le faisceau de lumière de mesure et le faisceau de lumière de référence après la propagation de manière alternée et faisant en sorte que les faisceaux de lumière interfèrent ;
une unité (12, 14, 21) de commande configurée pour commander la platine mobile (11) pour échantillon et l'interféromètre (3) ;
un photodétecteur (10) configuré pour convertir une intensité de lumière d'interférence obtenue par l'interféromètre (3) en un signal électrique ; et
une unité (21) de traitement de données configurée pour traiter un signal de sortie du photodétecteur (10),
le dispositif de mesure de profil de surface étant configuré pour commander la platine mobile (11) pour échantillon et l'interféromètre (3) dans une pluralité de positions d'échantillonnage sur la surface de test et pour soumettre un signal de sortie délivré en sortie du photodétecteur (10) à un traitement de calcul dans l'unité (21) de traitement de données pour ainsi mesurer un profil de surface de la surface de test, dans lequel
le plan standard (7) de l'interféromètre est un miroir plan, une orientation de surface du plan standard (7) est apte à s'incliner ou à tourner dans deux directions axiales orthogonales l'une par rapport à l'autre ou les deux orthogonales par rapport à un axe optique,
caractérisé en ce que l'unité (21) de commande est configurée pour changer, pour chacune de ladite pluralité de positions d'échantillonnage, l'orientation de surface du plan standard (7) dans les deux directions axiales et changer une position de la platine mobile (11) pour échantillon dans une direction le long d'un axe optique du faisceau de lumière de mesure pour ainsi changer la différence de chemin optique, le photodétecteur (10) est configuré pour convertir un changement d'intensité de la lumière d'interférence impliquée dans un changement de l'orientation de surface et de la différence de chemin optique en un signal électrique, l'unité (21) de traitement de données est configurée pour soumettre un changement du signal électrique à un traitement de calcul pour détecter des orientations de surface locales de la surface de test dans chacune des positions d'échantillonnage sur la surface de test,
dans lequel le dispositif de mesure de profil de surface inclut en outre une fonction d'obtention, à partir de données d'orientation de surface mesurées dans deux positions ou plus sur la surface de test, de valeurs de calcul de hauteur de surface de la surface de test dans les positions conformément à un traitement d'intégration.

12. Dispositif de mesure de profil de surface selon la revendication 11, dans lequel, dans la détection de l'orientation de surface locale, le dispositif de mesure de profil de surface est configuré pour changer l'orientation de surface du plan standard (7) vers une pluralité d'orientations d'une manière par pas dans les deux directions axiales, mettre en correspondance une fonction prédéterminée de distribution de contraste d'interférence avec un contraste d'interférence de la lumière d'interférence observée lorsque la différence de chemin optique est balayée dans une plage prédéterminée en utilisant, comme un nombre inconnu, une orientation de surface correspondant à une valeur maximum du contraste d'interférence, et pour calculer l'orientation de surface comme une orientation de surface à un moment où la fonction de distribution de contraste d'interférence correspond le plus à la valeur de contraste d'interférence.

13. Dispositif de mesure de profil de surface selon l'une quelconque des revendications 11 à 12, dans lequel le dispositif de mesure de profil de surface est configuré pour mesurer les deux d'une orientation de surface locale et d'une hauteur de la surface de test en utilisant un interférogramme (35) obtenu en une position quelconque sur la surface de test (7).

[FIG. 1]


(FIRST EMBODIMENT)
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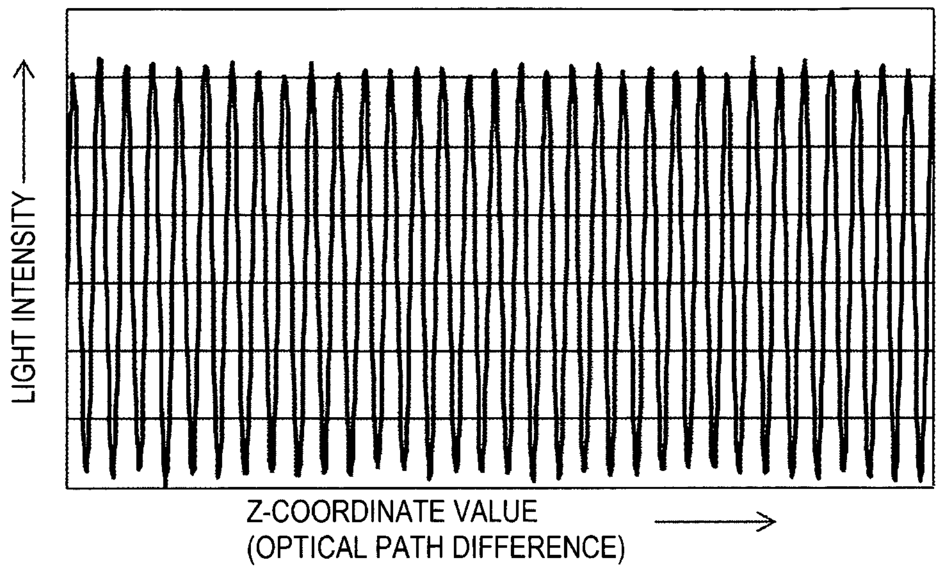
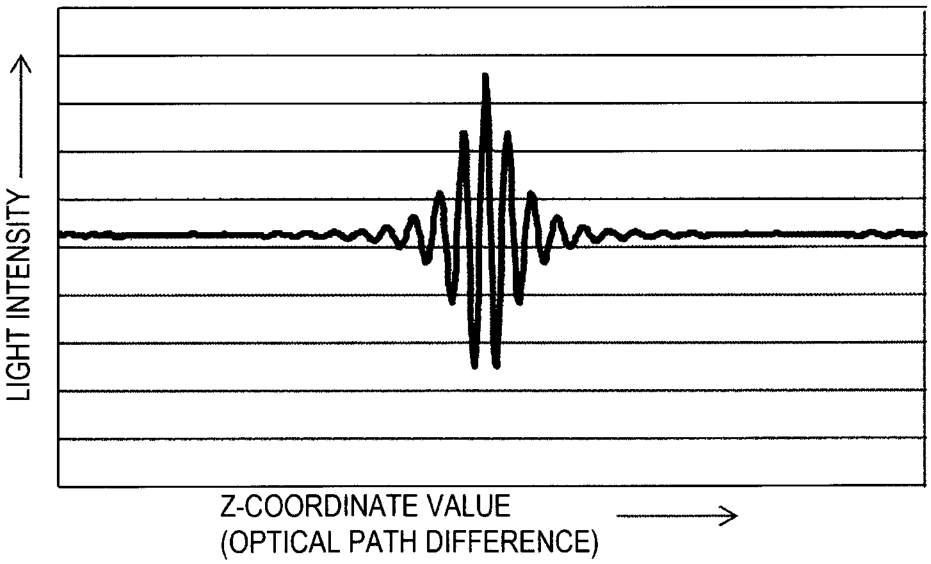
[FIG. 2a]


LIGHT INTENSITY
Z-COORDINATE VALUE
(OPTICAL PATH DIFFERENCE)

[FIG. 2b]


LIGHT INTENSITY
Z-COORDINATE VALUE
(OPTICAL PATH DIFFERENCE)

[FIG. 3]

STEP 1 GIVE COMMAND TO X-Y DRIVING/CONTROL UNIT 12 AND CAUSE X-Y DRIVING/CONTROL UNIT 12 TO MOVE X COORDINATE TO INITIAL VALUE POSITION

↓

STEP 2 REPEAT STEP 3 TO STEP 18 UNTIL X COORDINATE EXCEEDS END VALUE

↓

STEP 3 GIVE COMMAND TO X-Y DRIVING/CONTROL UNIT 12 AND CAUSE X-Y DRIVING/CONTROL UNIT 12 TO MOVE Y COORDINATE TO INITIAL VALUE POSITION

↓

STEP 4 REPEAT STEP 5 TO STEP 17 UNTIL Y COORDINATE EXCEEDS END VALUE

↓

STEP 5 GIVE COMMAND TO TILT-ANGLE CONTROL UNIT 18 AND CAUSE TILT-ANGLE CONTROL UNIT 18 TO MOVE θx TO INITIAL ANGLE POSITION

↓

STEP 6 REPEAT STEP 7 TO STEP 15 UNTIL θx EXCEEDS END VALUE

↓

STEP 7 GIVE COMMAND TO TILT-ANGLE CONTROL UNIT 18 AND CAUSE TILT-ANGLE CONTROL UNIT 18 TO MOVE θy TO INITIAL ANGLE POSITION

↓

STEP 8 REPEAT STEP 9 TO STEP 14 UNTIL θy EXCEEDS END VALUE

↓

STEP 9 GIVE COMMAND TO Z-AXIS CONTROL UNIT 14 AND CAUSE Z-AXIS CONTROL UNIT 14 TO MOVE Z COORDINATE TO INITIAL POSITION

↓

STEP 10 REPEAT STEP 11 TO STEP 12 UNTIL Z COORDINATE EXCEEDS END VALUE

↓

STEP 11 CAPTURE INTERFERENCE LIGHT INTENSITY SIGNAL 34

↓

STEP 12 GIVE COMMAND TO Z-AXIS CONTROL UNIT 14 AND CAUSE Z-AXIS CONTROL UNIT 14 TO MOVE Z COORDINATE BY PREDETERMINED PITCH

↓

STEP 13 CALCULATE MAXIMUM VALUE AND MINIMUM VALUE OUT OF PLURALITY OF INTERFERENCE LIGHT INTENSITY SIGNALS 34 OBTAINED BY MOVING Z COORDINATE IN STEP 9 TO STEP 12, CALCULATE INTERFERENCE CONTRAST 36 IN PRESENT ($\theta x, \theta y$), AND STORE INTERFERENCE CONTRAST 36 TOGETHER WITH SET OF PRESENT ($\theta x, \theta y$)

↓

STEP 14 GIVE COMMAND TO TILT-ANGLE CONTROL UNIT 18 AND CAUSE TILT-ANGLE CONTROL UNIT 18 TO MOVE θy BY PREDETERMINED PITCH

↓

STEP 15 GIVE COMMAND TO TILT-ANGLE CONTROL UNIT 18 AND CAUSE TILT-ANGLE CONTROL UNIT 18 TO MOVE θx BY PREDETERMINED PITCH

↓

STEP 16 CALCULATE MAXIMUM VALUE OF PLURALITY OF INTERFERENCE CONTRASTS 36 OBTAINED BY MOVING θx AND θy IN STEP 5 TO STEP 15 AND A SET OF ($\theta x, \theta y$) AT TIME OF MAXIMUM VALUE AND STORE SET OF ($\theta x, \theta y$) TOGETHER WITH SET OF PRESENT (X COORDINATE, Y COORDINATE)

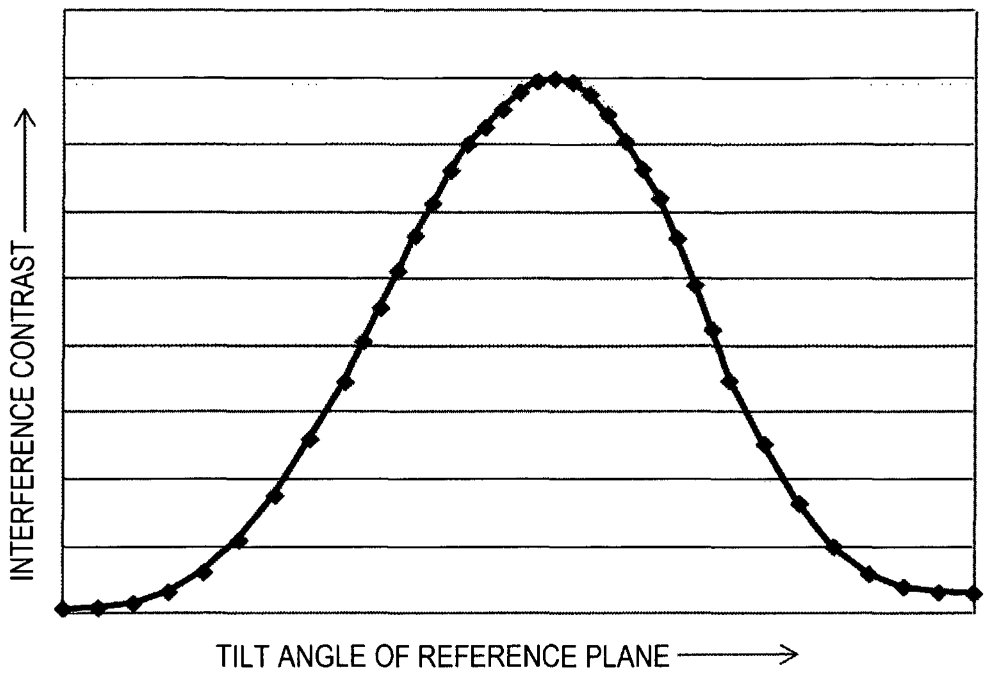
↓

STEP 17 GIVE COMMAND TO X-Y DRIVING/CONTROL UNIT 12 AND CAUSE X-Y DRIVING/CONTROL UNIT 12 TO MOVE Y COORDINATE BY PREDETERMINED PITCH

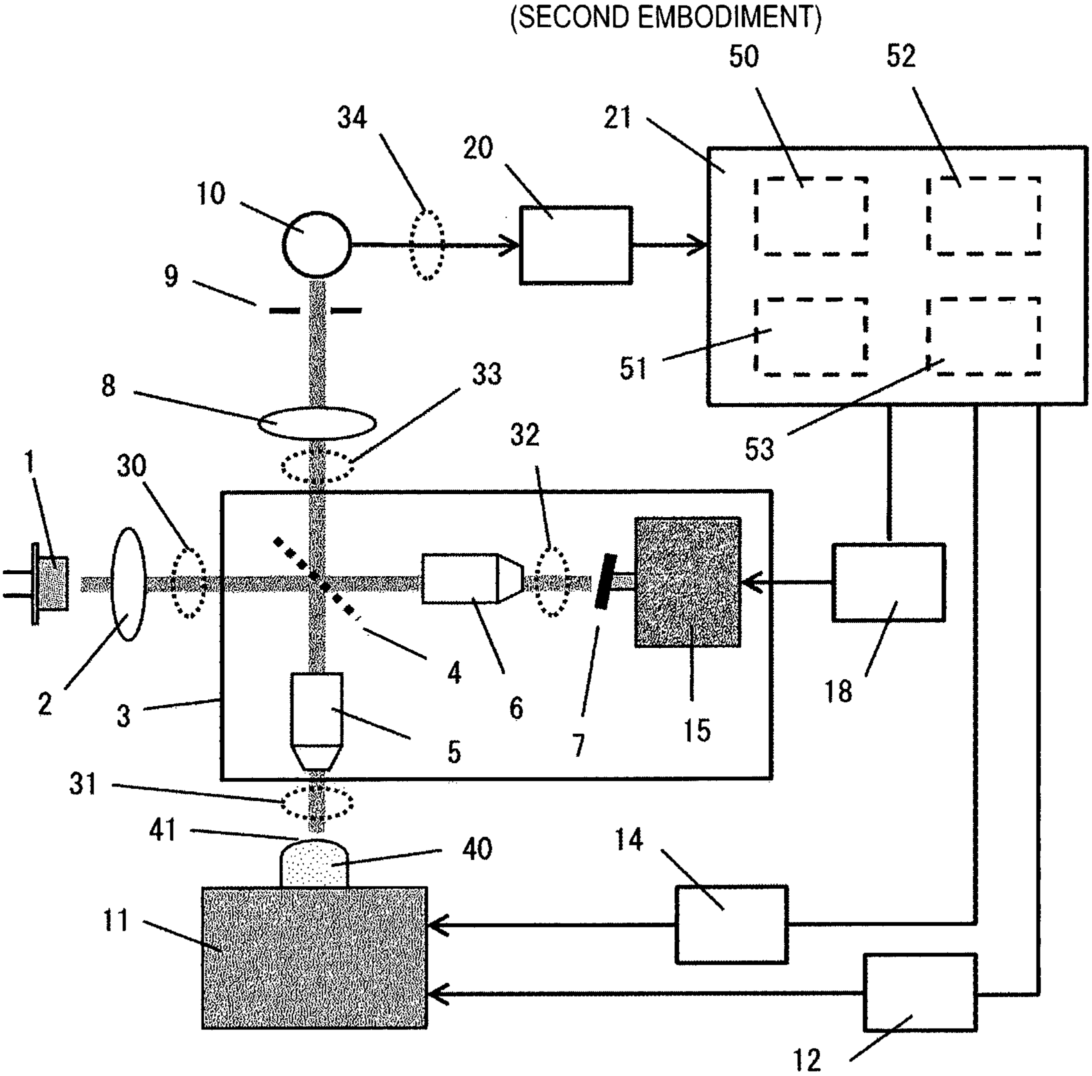
↓

STEP 18 GIVE COMMAND TO X-Y DRIVING/CONTROL UNIT 12 AND CAUSE X-Y DRIVING/CONTROL UNIT 12 TO MOVE X COORDINATE BY PREDETERMINED PITCH

[FIG. 4]



[FIG. 5]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REFERENCES CITED IN THE DESCRIPTION

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